J. P. Loosemore

Signal Control Circuits

British Practice

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J. P. LOOSEMORE

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The Institution of Railway Signal Engineers

SIGNAL CONTROL CIRCUITS

INTRODUCTION

Although this booklet is intended primarily to cover general principles of the design of signal control circuits it also includes details of signal indication circuits, the two subjects being closely associated. Furthermore, for the benefit of those who may not be acquainted with some of the apparatus to which reference is made, it has been considered necessary to describe briefly the salient features of the various signalling devices concerned. It has obviously been impossible to cover all the types of apparatus available and the circuit arrangements associated therewith, but the examples given have been selected from as wide a range as possible and should, therefore, serve to illustrate the principles involved.

The graphical symbols used in connection with the wiring diagrams are in accordance with the current British Standard Institution's Specification; these, being in common use on the British Railways, will doubtless be readily understood. Some Regions, however, employ different nomenclature to that used by others and therefore to avoid any misunderstanding the following definitions are given as a guide for those who may not be familiar with some of the terms used:—

HR	Relay controlling the caution aspect of a signal, i.e. the signal yellow indication.
HHR	Relay controlling the attention or restrictive aspect of a signal, i.e. the double yellow indication.
DR	Relay controlling the clear aspect of a signal.
RGK	Visual indicator repeating the danger aspect of a signal.
HGK	Visual indicator repeating the caution aspect of a signal.
HHGK	Visual indicator repeating the attention or restrictive aspect of a signl.
DGK	Visual indicator repeating the clear aspect of a signal.
ECR	Relay checking or proving the light in a signal.

It will be found that in all diagrams the actual circuits for the control of the various HR, HHR and DR relays have not been incorporated; these are detailed in booklet no. 8 when selection circuits are being considered.

ELECTRIC REPLACER FOR SEMAPHORE SIGNAL

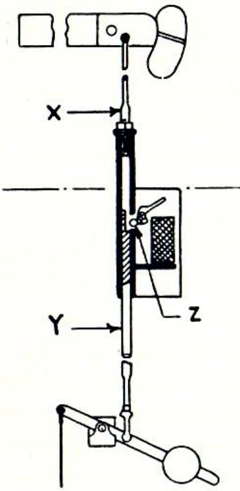


Fig. 1A.

Lever Normal
with
Replacer De-Energised

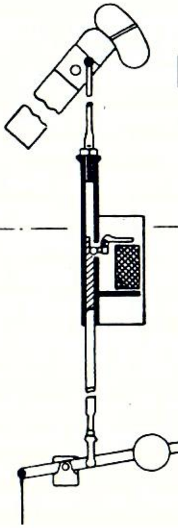


Fig. 1B.

Lever Reversed
with
Replacer
Energised.

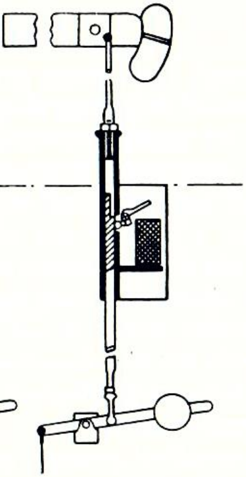


Fig. 1C.

Lever Left Reversed
with
Replacer De-Energised.

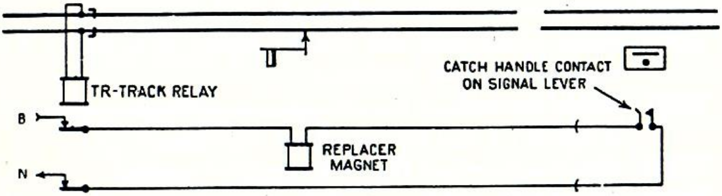


Fig. 2

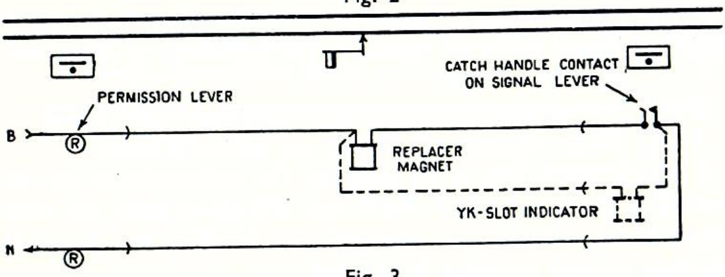


Fig. 3

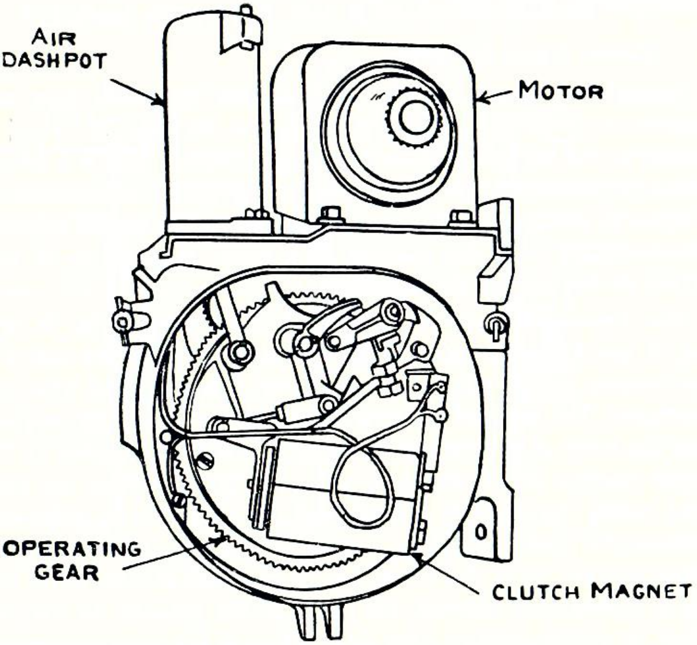
Semaphore Signals

Electric Signal Replacers

Semaphore signals of the mechanically operated type are sometimes controlled direct through the medium of, what is known as, an electric signal replacer or reverser. This is a device which is introduced into the mechanical operating connections of a signal to enable the signal to be returned to the danger position automatically with the passage of a train, irrespective of any action on the part of she signalman.

One type of replacer is illustrated diagrammatically in figs. 1A, B and C and is designed for inserting in the down rod of a mechanical signal, the actual down rod being divided into two portions. The replacer consists essentially of an electro-magnet, and the body of the casting to which it is fixed is coupled to the upper portion (x) of the down rod. The arrangements are such that when the magnet is energised its armature is attracted downwards thereby holding a roller (z) against a shoulder on the lower portion (y) of the down rod, so that any movement of rod (y) is transmitted through the body of the replacer to rod (x). Thus, it will be evident from fig. 1A that if the lever controlling the signal is pulled to the reverse position when the magnet is de-energised, rod (y) will merely complete its stroke by moving into the body of the replacer, but the replacer itself will remain stationary, and the signal will continue to display the danger aspect. If, however, the magnet is energised when the lever is pulled, as in fig. 1B, then rods (x) and (y) will in effect be coupled together and the upward movement of (y) will in turn push (x) upwards too, thus causing the signal to clear. When in this position, any interuption of the supply of current to the magnet will withdraw the restraint exerted on the movement of the roller by the armature crank thus allowing the replacer, and with it the signal arm, to return to danger by gravity as in fig. 1C. Before the signal can be cleared again its controlling lever must be returned to the normal position and the magnet re-energised.

Fig. 2 shows the electrical connections for a replacer of the type described in the foregoing, the circuit to the magnet in this case being taken over a front contact on a track circuit relay, so that when the track is occupied the signal will return to danger automatically. In order to economise in battery consumption



ELECTRIC SIGNAL MACHINE FOR SEMAPHORE SIGNALS
FIG. 4.

the circuit is also taken over a special catch handle contact on the signal control lever, thereby ensuring that, even though the track circuit is unoccupied, the magnet will only be energised when the catch rod is lifted to move the lever out of the normal position. The catch handle device has, of course, to be of the type in which the associated contact makes as soon as the lever is moved out of its normal position and remains "made" as long as it is out of that position. It will be appreciated, of course that a treadle or some such appliance could be used instead of a track circuit if necessary.

A signal replacer is sometimes used too, for slotting a signal which is controlled from two signal boxes. A typical circuit for such an arrangement is shown in fig. 3, the circuit in this case being taken over a reverse contact of a circuit breaker on the lever which is operated by the signalman giving permission for the signal to be cleared. The signal, of course, will not move from the danger position until the other signalman reverses his lever too, the replacer magnet remaining de-energised until he is ready to do so. Track circuit or treadle control can be introduced into the circuit as well if required; furthermore, an indicator can be incorporated, as shown dotted, in order to advise the signalman in the rear when permission has been given, from the box in advance, for the signal to be cleared.

Power-operated Signal Machines

In territories where the semaphore arm type of signal is retained, power-driven signal machines can be used with advantage for the operation of those signals which are too far from a signal box to permit of satisfactory working by mechanical means. For instance, they are particularly useful for the operation of remote distant signals and they are in fact, used extensively for this purpose.

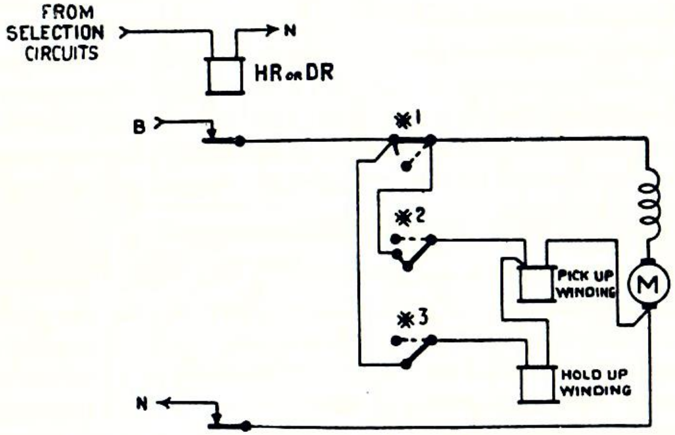
Two types of such machines are in general use, one arranged for all-electric control and the other for electro-pneumatic control

(*a*) *Electric Signal Machines* (*Fig.* 4)

Fundamentally, a signal machine comprises an electric motor, either of the d.c. or a.c. type, which operates the semaphore arm through a train of gears, a holding device being provided to retain the arm in the "off" position once it has been cleared.

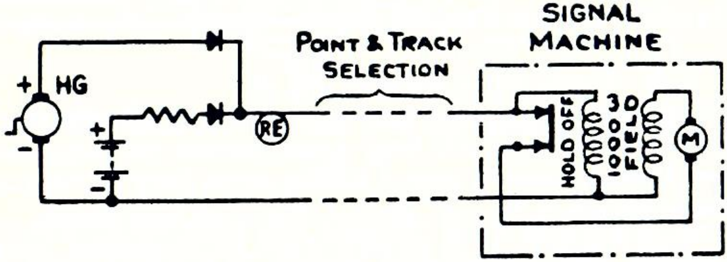
These machines can be arranged either for two-position lower quadrant or two and three-position upper quadrant working. Some are designed for bottom of post fixing, whilst others are suitable for top of post fixing. The former arrangement is more common where existing signals are concerned as the machine can then be fixed straight on to the post and the existing down rod connected up to the machine spindle through a crank. When top of post fixing is employed the semaphore arm and spectacle is usually coupled direct on to the spindle.

With some machines, the design is such that a dashpot is provided to retard the speed of the semaphore arm as it returns to the danger position by gravity, whereas others rely on the electrical characteristics of the motor acting as a generator, and discharging through a resistance, to provide this feature. Furthermore, some machines incorporate proving contacts for repeating circuits, etc., whilst others have no such provision and therefore



TYPICAL CONTROL CIRCUIT FOR ELECTRIC SIGNAL MACHINE

Fig. 5.



ELECTRIC SIGNAL MACHINE OPERATED BY HAND GENERATOR.

Fig. 6

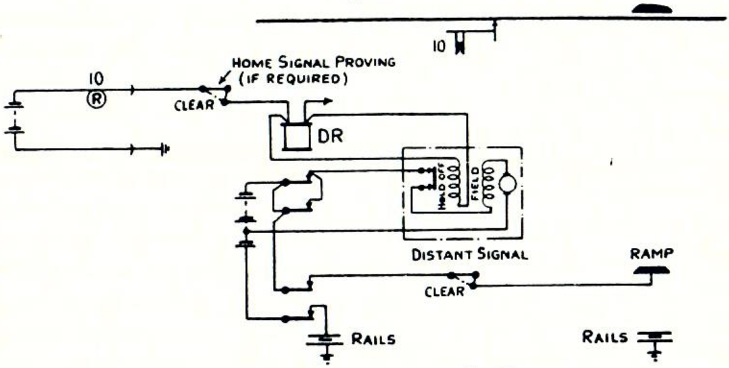


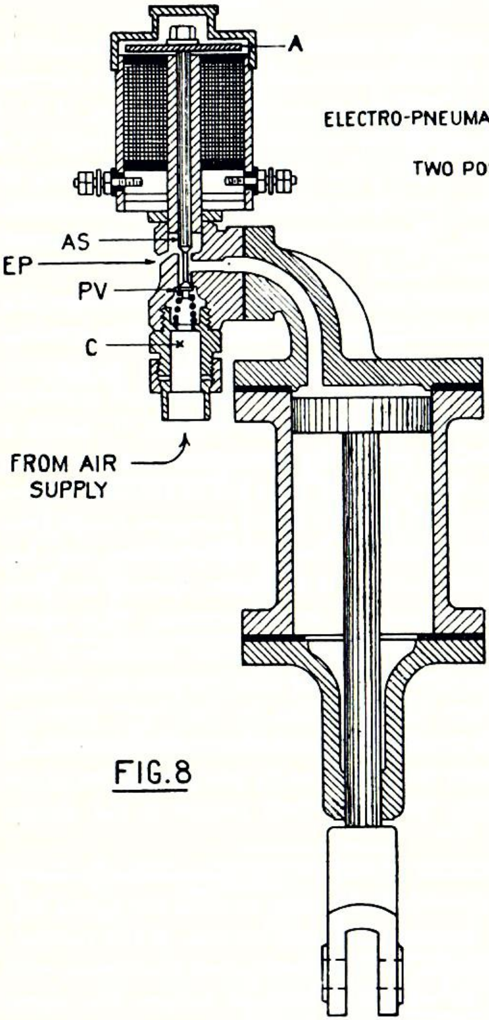
Fig. 7

necessitate the use of separate arm circuit breakers if such facilities are required. This latter arrangement has, however, the advantage of actually proving the position of the semaphore arm.

As many of these machines are employed in remote districts where a power supply is either unavailable or unreliable, thereby necessitating the use of primary or secondary batteries, it is of course, essential to minimise the current required to "hold" the signal in the clear position. For this reason the holding-off devices for various d.c. machines although differing in design, invariably employ high resistance windings to limit the current required for this purpose.

Fig. 5 shows the wiring for a two-position low-voltage d.c. machines but will serve to illustrate the general principles involved with all types of machines. It will be seen that the supply over the control relay contact is taken through the field and armature of the motor via an arm circuit controller contact *1, which is closed during the period in which the semaphore arm is moving from the danger to the clear position. Just before the arm reaches this point another contact *2 is made which energises the pick-up winding of the holding mechanism. As soon as the arm has reached the clear position contact *1 is broken, thereby isolating the motor field and armature, but another contact *3 is closed immediately which brings the high resistance winding of the holding mechanism into circuit in series with the pick-up winding and the semaphore arm thus remains in the "off" position. When the control relay is de-energised, either for instance, by returning the signal lever to normal or by the occupation of the controlling track circuit, the signal will return to the danger position by gravity.

An interesting application of electric signal machines is shown in fig. 6. In this case the electrical energy to wind the signal "off" is taken from a hand generator set and because of the comparatively high voltage (about 100 volts) obtained therefrom, with consequent reduction in operating current values, the signal controls can be taken direct over the selection contacts thus obviating the necessity for a separate control relay. A battery is, of course, also required, as shown, for providing a source of supply for the hold-off coils, as otherwise the signalman would have to rotate the handle of the generator set as long as the



ELECTRO-PNEUMATIC SIGNAL MECHANISM
FOR
TWO POSITION SEMAPHORE

FIG. 8

signal is to remain in the clear position; the size and capacity of this battery will, however, be very much smaller than would be required if it had to cater for operation as well. The rectifiers are included in the circuit to prevent the battery feeding back on to the generator and vice versa. It should be noted too that in this instance the design of the machine is such that the hold-off winding is in parallel with the motor field and armature, and therefore energised as soon as the signal starts to move from the danger position. When the signal is fully clear the motor cut-out contact is opened.

The adaptability of signal machines will be further evident from fig. 7 as in this case a local battery is used for operating the machine whilst the signal box battery is employed for holding-off purposes. This illustration is taken from a typical installation in this country, in territory where an automatic warning system is in operation, the signal concerned being a power operated distant signal. With the type of A.W.S. in question, a ramp, situated between the running rails, has to be supplied with electrical energy when the distant signal is "off", the necessary connections being shown only as a matter of interest, but the point to be noted is that a local battery would in any case be required whether the signal is power operated or not.

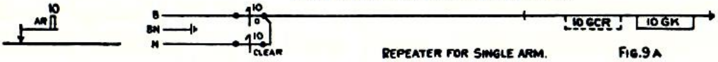
Electro-Pneumatic Signal Mechanisms

Electro-pneumatic signal mechanisms are simple in construction and although their design varies slightly according to the type of signal concerned, the principle on which they operate is uniform throughout.

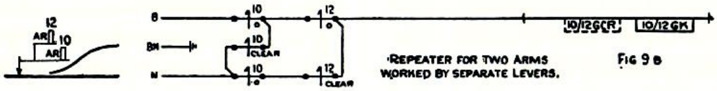
A typical two-position machine is shown in diagrammatic section in fig. 8, and comprises an electro-magnet, which can be either of the d.c. or a.c. type, bolted direct to an air cylinder, the piston of which operates the semaphore arm and spectacle by means of a straight push or pull movement. The compressed air supply is connected to the chamber "C" and, under normal conditions, the pin valve "PV" is kept on its seating by the air pressure, whilst the air cylinder is left open to atmosphere through exhaust port "EP." When the magnet is energised its armature "A" is attracted downwards and the armature stem "AS" closes the exhaust port and unseats the pin valve by pushing on its pin. The compressed air then passes into the air cylinder and the semaphore arm is moved to the clear or caution position by the piston. As soon as the circuit to the magnet is interrupted, the magnet becomes de-energised and the pin valve re-seats, pushing up the armature stem and opening the exhaust port once more allowing the air cylinder to exhaust to atmosphere. When pressure has been removed from the cylinder the signal returns to the danger position by gravity and the piston is pushed back to its normal position, the size of the exhaust port being such that a cushioning effect is produced during this process.

As with such an arrangement, electrical energy is used only as a means of controlling the admission of compressed air to the operating cylinder, by energising the associated magnets, it will be evident that the current values are very small. A separate control relay is, therefore, unnecessary as the operating circuit can be taken direct over a reverse contact on the signal lever and

SEMAPHORE ARM REPEATER CIRCUITS.



REPEATER FOR SINGLE ARM. FIG. 9A



REPEATER FOR TWO ARMS WORKED BY SEPARATE LEVERS. FIG 9B

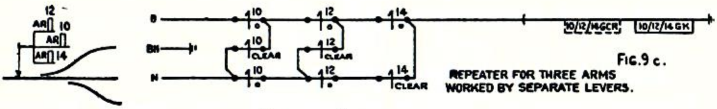
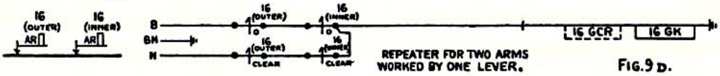
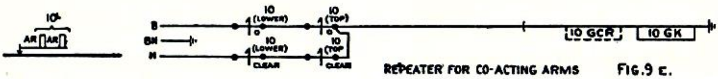


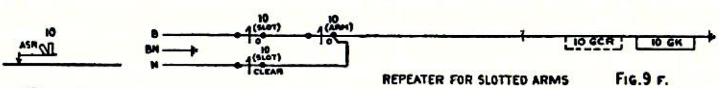
FIG. 9C. REPEATER FOR THREE ARMS WORKED BY SEPARATE LEVERS.



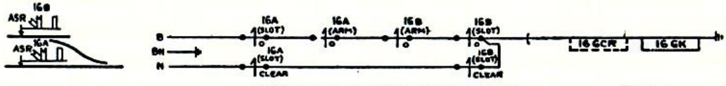
REPEATER FOR TWO ARMS WORKED BY ONE LEVER. FIG. 9D.



REPEATER FOR CO-ACTING ARMS FIG. 9E.



REPEATER FOR SLOTTED ARMS FIG. 9F.



REPEATER FOR TWO SLOTTED SIGNALS WORKED BY SAME LEVER. FIG. 9G.

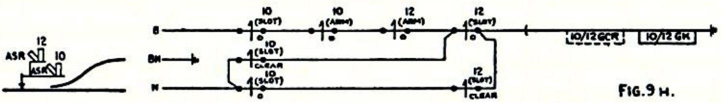


FIG. 9H.

REPEATER FOR TWO SLOTTED SIGNALS WORKED BY SEPARATE LEVERS.

front contacts on the controlling tack circuit relays, etc. Only one line wire, and a return is required for the control of each two-position signal.

Three-position signal mechanisms are provided with two magnets (45° and 90° controls) the arrangements being such that the air supply to the 90° valve magnet passes through the 45° valve magnet. Consequently it is impossible for a signal to move from the danger to the 90° position unless the 45° magnet is also energised. The 45° and 90° control circuits can therefore be taken direct to their respective magnets, again without the need for a separate control relay, thus simplifying the circuit arrangements.

It has been considered unnecessary to show the actual control circuits in this case as it is hoped that these will be obvious from the preceding notes.

Semaphore Arm and Light Repeaters

Where the location of a running signal is such that it is impossible to see from the signal box whether it has responded correctly to the movement of its controlling lever, it is usual to provide a repeater to indicate to the signalman the aspect displayed. To do this a circuit breaker is coupled to the semaphore arm and a polarised circuit, fed from a local centre-tapped battery, is used to operate a three-position indicator in the signal box, the indicator showing "ON or "OFF", if the signal is in the correct danger or clear position and "WRONG" if it is in neither of these positions.

Typical circuit arrangements for single semaphore arms and various combinations of signals are shown in figs. 9A-9H. It will be noted that a separate signal proving relay (GCR) is shown dotted in each diagram: this is usually incorporated when it is necessary to prove the position of the semaphore arm for electric lock circuits, etc., the relay being of the polarised type. In some cases the relay forms an integral part of the indicator depending, of course, on the type of indicator used.

It is thought that the illustrations will be self-explanatory, but taking fig. 9A as an example, it will be seen that when signal 10 is at danger the positive of the battery is connected to the left-hand side of the indicator, returning to negative via earth, thus deflecting the indicator to one side. When the signal is in the clear position the positive will be applied to the right-hand side

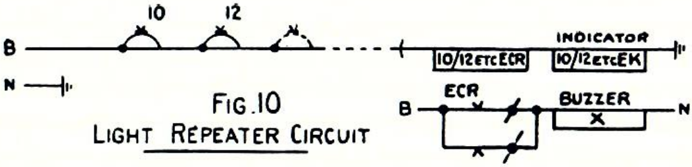


FIG. 10

LIGHT REPEATER CIRCUIT

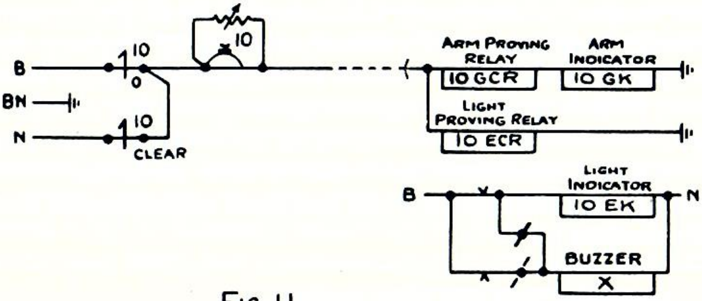


FIG. 11.

SEMAPHORE ARM AND LIGHT REPEATER CIRCUIT

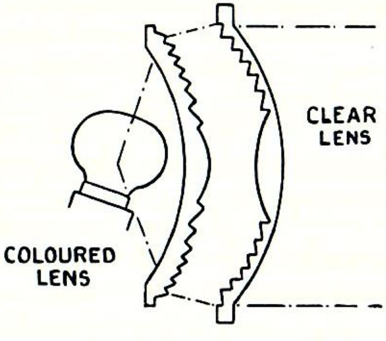


FIG. 12.

MULTIPLE UNIT COLOUR LIGHT SIGNAL.

of the indicator, via earth, returning to negative over the line wire, thereby deflecting the indicator in the opposite direction. If, however, due to the positioning of the semaphore arm neither of the circuit breaker contacts are correctly made, the circuit will be incomplete and the indicator will therefore assume the neural or "WRONG" position.

Where a slotted signal is concerned it is generally considered sufficient to prove the arm and the slot in the danger position but the slot only in the clear position.

In addition to repeating the position of certain semaphore arms, it is usual to provide an indication in the signal box to show that the signal lamps are correctly alight. To do this, a device known as a lamp expander is fitted over the flame of the oil lamp in each signal concerned, the expander being so designed that the heat from the flame causes certain metal components of differing characteristics, to expand and make a contact, this contact being included in the electrical repeating circuit. The general practice is to combine the repeating of all the signals on one side of the signal box, both for the "Up " and "Down" lines, on one indicator. The expander contacts for each group are connected in series as shown in fig. 10. Here again, a separate lamp proving relay (ECR) has been shown, but this sometimes forms a part of the actual indicator. A contact on the proving relay can be employed to provide an audible indication in the event of a lamp failure, a switch being incorporated to stop this working if necessary, for instance during daylight hours. With the arrangements shown, when the switch is in the normal position the failure of a lamp will cause the buzzer to operate, and the signalman, having thus had his attention drawn to the fact, can then stop the buzzer while the lineman is investigating the failure. As soon as the fault has been rectified, the re-energisation of the proving relay will once again result in the operation of the buzzer, as the switch will then be out of its normal position; thus, the signalman will be advised that the lamps are correctly alight once more and must replace his switch to normal.

Where only one signal light is concerned, the repeating of this is often combined with the repeating of its semaphore arm in the manner shown in fig. 11. A resistance is placed in parallel with the lamp expander contact so that a failure of the signal lamp, although resulting in a "light-out" indication being given,

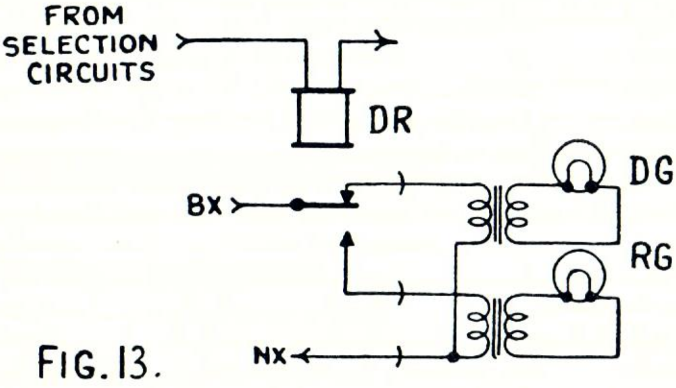


FIG. 13.

TYPICAL CONTROL CIRCUIT
FOR TWO-ASPECT COLOUR LIGHT SIGNAL.

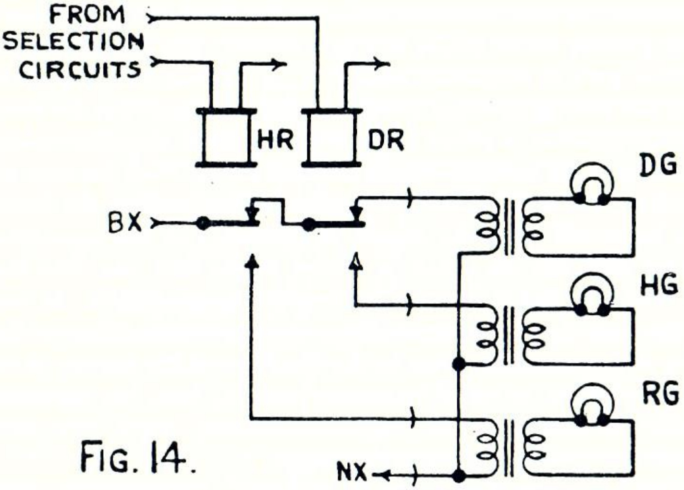


FIG. 14.

TYPICAL CONTROL CIRCUIT FOR
THREE ASPECT COLOUR LIGHT SIGNAL.

will not interfere with the arm indication. It will be appreciated that when the resistance is in circuit a smaller current will be flowing; this will be sufficient to operate the arm proving relay and indicator but not the lamp proving relay.

Colour-Light Signals

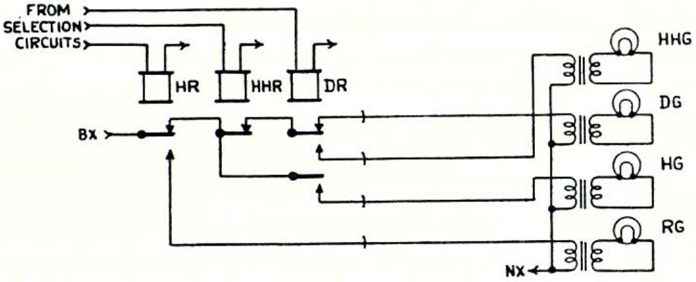
Multiple-unit-type (fig. 12)

Colour-light signals of the multi-unit type have no moving parts, a separate light unit being provided for each aspect to be displayed. The light units comprise a concentrated filament lamp working in conjunction with a combination lens arrangement, the outer lens being of clear glass and the inner lens of the desired colour. The lamp filament is located at the focal centre of the lens system in order to obtain maximum beam intensity. Where side-light units are provided, these also take the form of a separate lamp and optical system for each aspect, the side-light lamp being wired in parallel with the lamp for the main aspect with which it is associated. Individual lighting transformers are usually provided too, for each aspect, depending on the nature of the lighting supply available.

The control circuits for colour-light signals of the multi-unit type are extremely simple, as will be evident from the typical wiring diagram for a two-aspect signal shown in fig. 13. It will be seen that a control relay is required, the condition of this determining which aspect is to be illuminated. For instance, when the relay is de-energised, a circuit will be completed over its back contact from the lighting supply BX to the transformer in the bottom aspect of the signal; if the relay is energised then this feed will be transferred to the transformer in the top aspect via a front contact on the relay.

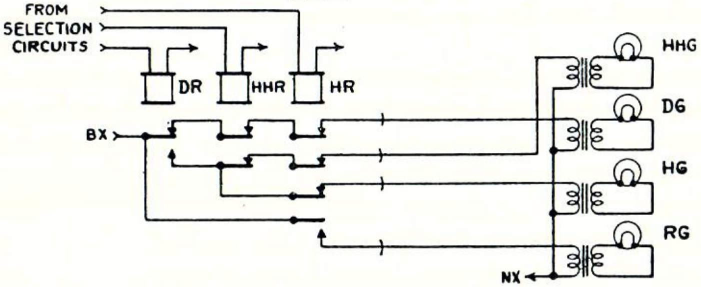
Where a three-aspect signal is concerned, an additional control relay is necessary as shown in fig. 14. In this case, if the HR is de-energised, the red aspect will be illuminated, irrespective of the condition of the DR. If, however, the HR is energised, then the signal will display either a yellow or a green aspect depending on whether the DR is making its back or front contact respectively.

For a four-aspect signal, a third control relay is introduced into the arrangements, as illustrated in fig. 15. Here again, it



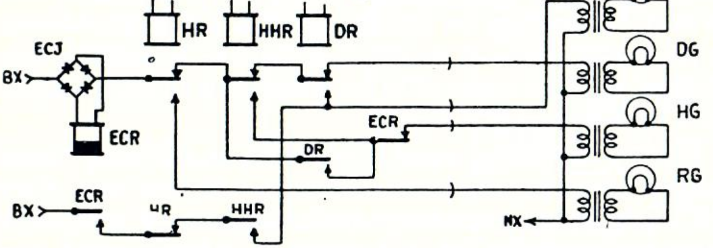
TYPICAL CONTROL CIRCUIT FOR FOUR-ASPECT COLOUR LIGHT SIGNAL

FIG. 15.



ALTERNATIVE CONTROL CIRCUIT FOR FOUR-ASPECT COLOUR LIGHT SIGNAL

FIG. 15A.



TYPICAL CONTROL CIRCUIT FOR FOUR-ASPECT COLOUR LIGHT SIGNAL
WITH PROVISION FOR AN ALTERNATIVE INDICATION IN THE
EVENT OF A LAMP FAILURE IN THE SINGLE YELLOW ASPECT.

FIG. 16.

will be noted that as long as the HR is de-energised, the signal will display a red aspect. With the HR energised, however ,a single yellow indication will be given if the HHR and DR are both de-energised, and a double yellow indication if the HHR is energised and the DR de-energised. When all three relays are energised the green aspect of the signal will be illuminated.

It should be realised that figs. 14 and 15 are only intended to illustrate the principles involved in the control of three-aspect and four-aspect signals and that, although they do in fact depict the methods more usually adopted, the positioning of the various relay contacts can be rearranged if so desired. An alternative arrangement for a four-aspect signal is shown in fig. 15A.

With four-aspect signals, provision is sometimes made for an alternative indication to be given in the event of a complete failure of the lamp in the signal yellow aspect; it is argued that as high speed trains are concerned it is even more important to maintain this aspect than the red. For instance, if the light is out in a signal which should be displaying a yellow aspect and a driver fails to notice this signal, then his train may be travelling at too high a speed when he first sees the red aspect of the next signal to pull up in time. On the other hand, if the lamp failure is in connection with the red aspect of a signal then presumably the train would be travelling at a reduced speed, the previous signal having been at yellow, and the driver should therefore, be in a better position to notice this failure. Fig. 16 shows one method which can be adopted in this connection, the arrangements being such that when the lamp in the signal yellow aspect (HG) fails, the second yellow aspect (HHG) will be illuminated. It will be seen that a rectifier (ECJ) is inserted in the normal supply to the signal and a relay (ECR) is connected across it which will be energised as long as current is flowing in the circuit. If the yellow lamp burns out, however, when the signal should be displaying the caution aspect, relay ECR will become de-energised and a circuit will be completed over its back contact through a front contact on the HR and a back contact on the HHR to the HHG light unit. A front contact of the ECR is included in the circuit to the HG light unit to isolate this in the event of a failure, the ECR must therefore be provided with a slow release feature to ensure that, when normal working is in operation, it will remain energised during the period in which the HR is breaking

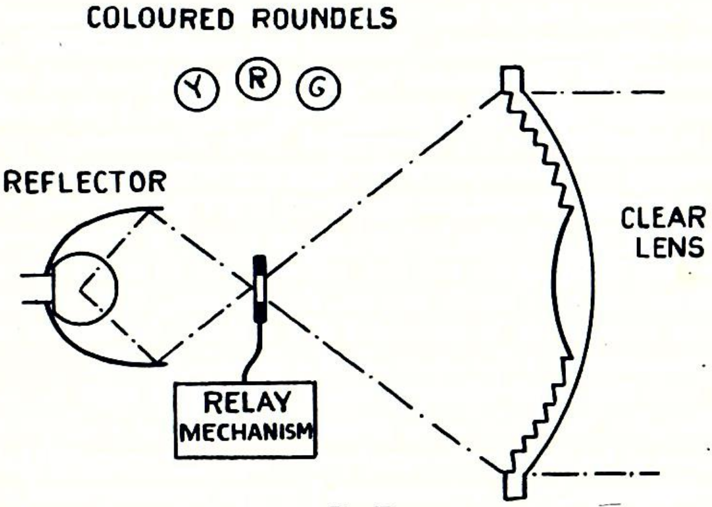


Fig. 17

TYPICAL CONTROL CIRCUITS
FOR
TWO-ASPECT SEARCHLIGHT SIGNALS.

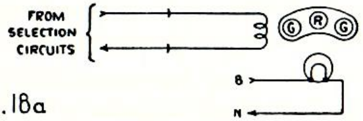


FIG. 18a

D.C. SIGNAL CONTROLLED
FROM D.C. SUPPLY

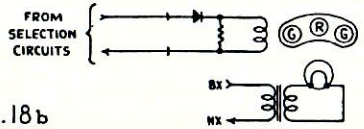


FIG. 18b

D.C SIGNAL CONTROLLED
FROM A.C. SUPPLY

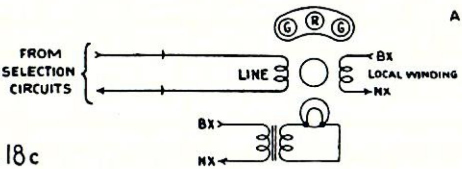


FIG. 18c

A.C. SIGNAL CONTROLLED
FROM A.C. SUPPLY

its back contact and making its front contact when the signal is being changed from red to yellow.

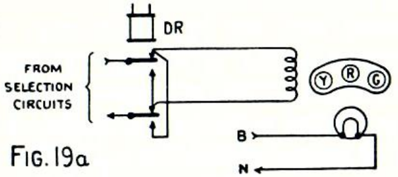
Searchlight Type (fig. 17)

Searchlight signals are fitted with one light unit only; the lamp used with this is somewhat similar to that provided in a signal of the multi-unit type but a clear lens only is employed and a reflector is incorporated to further intensify the beam. The employment of a reflector is, of course, permissible in this case as the possibility of a "phantom" or false indication arising from direct rays of the sun or extraneous light does not exist. The various aspects are obtained by placing a glass disc of the appropriate colour in front of the lamp. To do this, a three-position relay mechanism is included in the signal and a small spectacle device, carrying three coloured glasses, is coupled to its armature shaft in such a way that the condition of the relay determines which glass is in front of the lamp. For instance, for a three-aspect signal the glasses would be coloured yellow, red and green; with the relay in the de-energised or neutral position the light from the lamp would pass through the red glass, whereas with the relay energised either the yellow or the green glass would take up a position in front of the lamp depending on the direction in which the relay is energised, a polarised circuit being usually employed. For a two-aspect signal only glasses of two colours would be fitted.

The signal relay can be arranged for operation on a.c. or d.c. The a.c. relay is designed on somewhat similar lines to a standard two-element three-position vane relay, whereas, the d.c. relay employs a permanent magnet arrangement instead of a local winding. Both types of relay are provided with counterweights so that they will return to their neutral or central positions by gravity when de-energised.

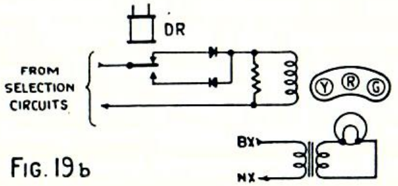
Typical circuits for the control of two-aspect signals are shown in figs. 18*a*, *b* and *c*, from which it will be noted that the signal relay takes the place of the control relay which would be required for a two-aspect signal of the multi-unit type. Although a three-position relay is used, a polarised circuit is unnecessary as the signal is arranged to display either a clear or danger aspect depending on whether the relay is energised or de-energised. It is usual, therefore, to fit the glass to give the most restrictive

TYPICAL CONTROL CIRCUITS
FOR
THREE-ASPECT SEARCHLIGHT SIGNALS.



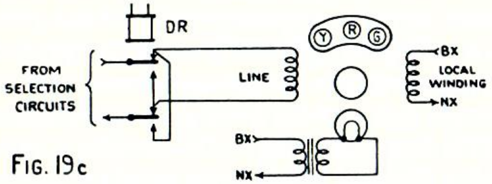
D.C. SIGNAL CONTROLLED
FROM D.C. SUPPLY

FIG. 19a



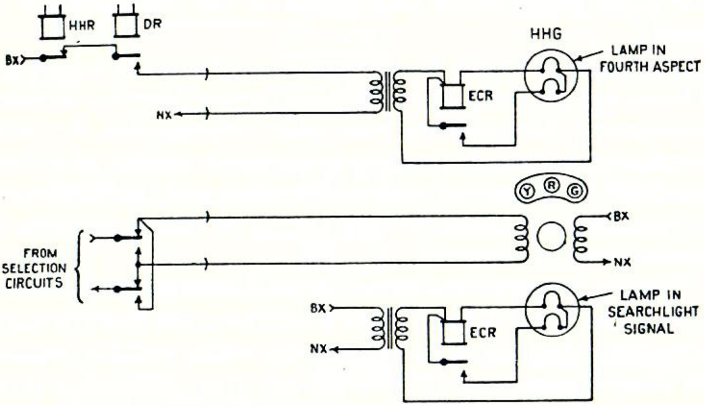
D.C. SIGNAL CONTROLLED
FROM A.C. SUPPLY

FIG. 19b



A.C. SIGNAL CONTROLLED
FROM A.C. SUPPLY

FIG. 19c



TYPICAL CONTROL CIRCUIT FOR FOUR-ASPECT SEARCHLIGHT SIGNAL

FIG. 20.

aspect in the centre position of the three-aspect spectacle and to fit "clear" glasses of the same colour on each side of it so that no matter in which direction the relay is energised the same clear aspect will be displayed. Often, even though an a.c. supply is available preference is given to the d.c. type of signal because of the reduced power consumption consequent upon the use of the permanent magnet system; in such cases, the a.c. supply can be used for the line circuits as shown in fig. 18*b* by incorporating a half-wave rectifier and resistance in the signal to enable the use of a d.c. relay mechanism. A separate rectifier and transformer unit can, of course, be employed at the signal location to achieve the same results, but this must be of special design to overcome the possibility of energising the relay by induced currents as a result of capacity effects on the lines where multi-core cables are used.

Similar arrangements, adapted for the control of three-aspect signals, are shown in figs. 19*a*, *b* and *c*. The DR is used in these cases for polarising purposes; this can be located in the signal box or in an apparatus case adjacent to the signal, whichever arrangement is more convenient. These diagrams will doubtless be self-explanatory, but it might be as well to point out that the additional half-wave rectifier which is shown in fig. 19*b* is incorporated in such a way that the direction of the operating current to the signal is dependent on the condition of the DR relay, i.e. whether energised or de-energised.

Where automatic signals of the alternating current type are employed, arrangements are sometimes made to place the lamp in series with the local winding so that should the lamp fail this mechanism will return to the neutral or danger position and the signal in the rear would display a more restrictive aspect, thus in effect changing two sections into one.

If a fourth aspect is required where searchlight signals are employed this is often provided by fitting a single-aspect signal of the multi-unit type on top of the searchlight signal. With such a unit, a reflector cannot, of course, be used in the additional aspect as otherwise a false indication might be given by rays of sunlight passing into the unit and being reflected back through the lens system; therefore, in order to provide an indication of the same brilliancy as that given by the searchlight signal, a higher wattage lamp is usually employed. Fig. 20 shows the typical wiring arrangement for a four-aspect signal of the searchlight type. It will be seen that the three-aspect portion of the signal can be controlled as in figs. 19*a*, *b* and *c*, a separate control being provided for the fourth aspect by the provision of an additional HHR relay.

Lamps for Colour-light Signals

Considerable research has been carried out in regard to the design of electric lamps for colour-light signals as these lamps obviously play an important part in the operation of such signals. Three types of lamps are in common use, these are:—

(*a*) Single filament type;

TYPICAL INDICATION CIRCUITS
FOR
MULTI-UNIT COLOUR LIGHT SIGNALS.

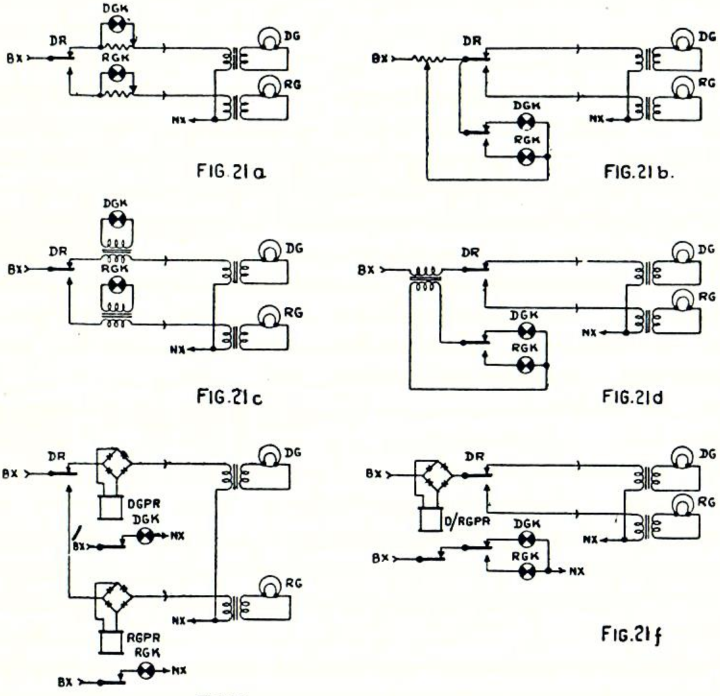


FIG. 21a FIG. 21b. FIG. 21c FIG. 21d FIG. 21e FIG. 21f

(*b*) Double filament type, with main and auxiliary filaments connected permanently in parallel;

(*c*) Double filament type, with independently connected filaments, a proving relay being inserted in series with the main filament. The connections to the auxiliary filament are taken over a back contact on the proving relay so that this filament is not brought into service until the main filament has burnt out, as shown in fig. 20.

With the high standard at present obtaining in the manufacture of electric lamps there is no reason why the single filament type should not give satisfactory service, providing each lamp is replaced well within its rated lifetime. There is, however, always the possibility of a premature failure of the lamp filament, thus giving a negative indication, and for this reason the double filament type of lamp is generally preferred.

Where the auxiliary filament is connected permanently in parallel with the main filament as in "*b*" the auxiliary filament is rated at a higher voltage than the main filament and therefore, being under-run, its life should be longer than that of the main filament. A beam of reduced intensity will be given when the main filament has burnt out, and although this will be of sufficient brilliancy to allow the train service to continue, the failure will be apparent and a lineman can thus arrange for the lamp to be replaced.

Where lamps with independent filaments are used the auxiliary filament is new when brought into operation. This is considered an advantage by some, as it is argued that with the other type of double filament lamp the auxiliary filament, even though under-run, is in service throughout the lifetime of the main filament and is therefore liable to a premature failure when the main filament has burnt out. With lamps of this type, arrangements can be provided for the auxiliary filament to provide a beam of almost equal intensity to that given by the main filament, as the failure of the main filament will be evident from a regular inspection of the proving relay associated therewith. The auxiliary filament is in this case, rated for a higher wattage than the main filament as it is necessarily located slightly away from the focal centre of the optical system.

TYPICAL INDICATION CIRCUITS
FOR
SEARCHLIGHT SIGNALS

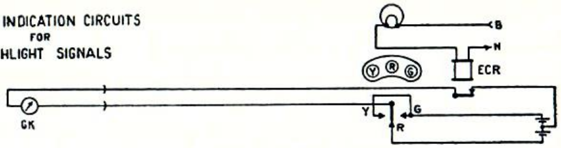


FIG.22A

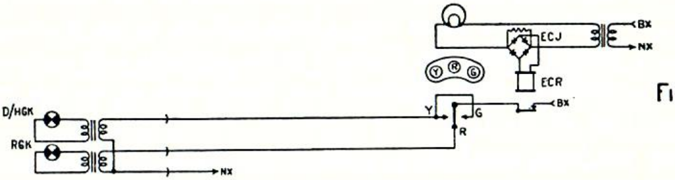


FIG.22B

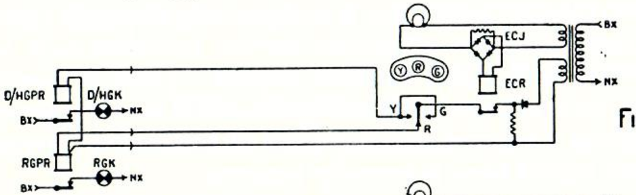


FIG.22C

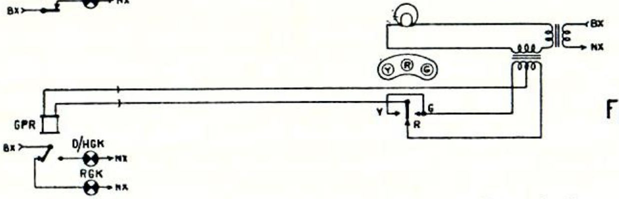
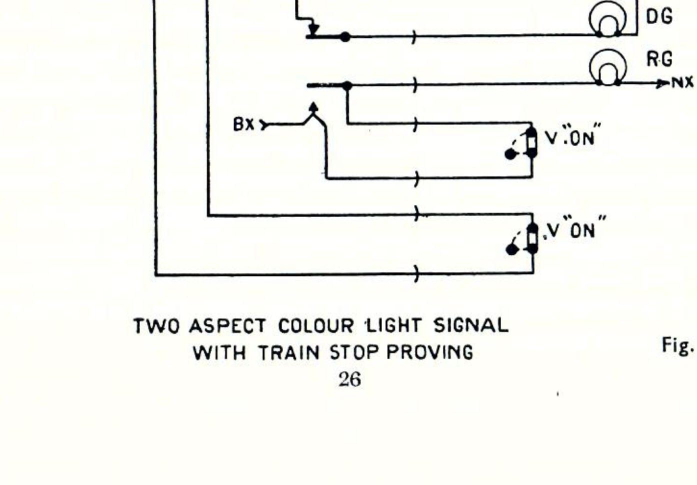


FIG.22D



TWO ASPECT COLOUR LIGHT SIGNAL
WITH TRAIN STOP PROVING

Fig. 23

Indication Circuits for Colour-light Signals

It is usual to provide indicators in the signal box to repeat the condition of all the colour-light signals controlled therefrom. Where two-aspect signals are concerned both aspects are indicated. For three and four-aspect signals, however, it is often considered sufficient to give a combined indication for all the "off" aspects. Sometimes too, when the signals are fitted with independent filament lamps, it is even considered unnecessary to prove the lamp in the indication circuits.

Several indicating arrangements are shown in fig. 21, these being applicable to two-aspect signals of the multi-unit type. In the first example, fig. 21*a*, a resistance is inserted in series with each of the supply leads to the signal and the voltage drop across each resistance is used to light an indicating lamp. When this method is used in conjunction with signals employing double-filament lamps with both filaments in parallel, the failure of the main filament will be denoted by a reduction in the brilliancy of the indication lamp. A variation of this arrangement is shown in fig. 21*b*, where only one resistance is used, the indication lamp to be illuminated being selected over contacts on the associated signal control relay. The latter method would obvoiusly be uneconomical if the necessary relay contacts were not available on existing relays.

The arrangements shown in figs. 21*c* and 21*d* are somewhat similar to the series resistance method, but special transformers are used in lieu of resistances.

In figs. 21*e* and 21*f*, the current for lighting the signal is taken through a rectifier with the result that the relay associated therewith, will be energised as long as the signal lamp is intact, or in other words as long as current is flowing in the circuit. As will be seen from these diagrams, the indication lamp circuits can be taken over contacts on the proving relays and of course, contacts on the control relays where only one rectifier and relay is used. The proving relays can be designed to drop-away when the main filament of the signal lamp has failed. The advantage of this system is that the failure of the indicating lamp will not affect the brilliancy of the signal lamp and of course, extra contacts can be fitted on the proving relays for electric-lock circuits.

With searchlight signals, the signal relay is fitted with contacts which can be used for repeating circuits. It is, however, necessary to provide some additional means for proving the lamp as it will be obvious that even though the signal relay has responded correctly to the lever movement, the signal will not be displaying the required aspect unless the light is illuminated.

Some typical indication circuits for providing "on" and "off" indications for three-aspect signals of the searchlight type are shown in fig. 22; various other arrangements will no doubt be called to mind. In order to simplify these diagrams a three position polar contact has been shown in connection with the signal relay, but, in actual fact, independent contacts for each position are usually fitted. Fig. 22*a* shows a polarised circuit for operating a needle type indicator, the proving relay in series with the lamp filament proving the intactness of that filament. The arrangements shown in figs. 22*b* and 22*c* include provision for lamp and spectacle proving in conjunction with indication transformers on the one hand and relays on the other. In fig. 22*d* another polarised circuit arrangement is shown but in this case a lamp proving relay is not provided, a special transformer with centre tapped secondary winding being inserted in series with the lamp filament in such a way that the wiring of this, in conjunction with the signal relay proving contacts, determines the direction in which the indication current is flowing.

Train Stop Proving Circuits

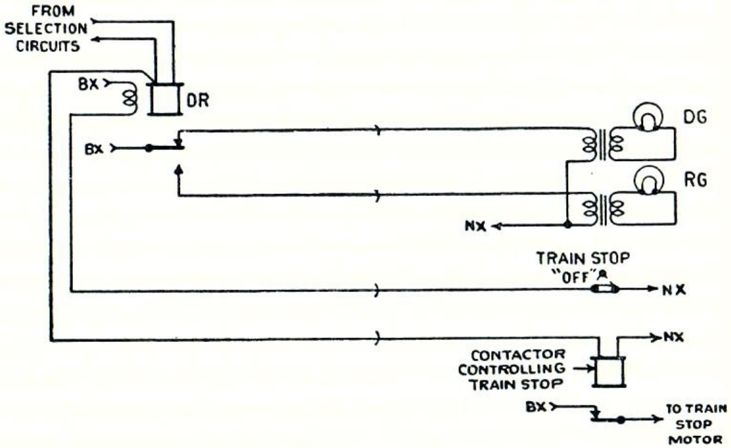
A train stop is a device which is fixed on the track and works in conjunction with a stop signal, the train stop being provided with a trip arm which engages with a trip cock on the locomotive (or driving end of multi-unit electric stock) when the signal is at danger, thereby resulting in the automatic application of the brakes. When conditions are such that the signal can be cleared, the train stop arm is lowered so that it will not come into contact with the brake mechanism.

Where train stops are employed, it is usual to prove that these have operated correctly before a clear signal can be displayed. A typical arrangement in this connection is shown in fig. 23, from which it will be seen that the energisation of the signal control relay will complete a circuit to the green light in the signal and one to the magnet which controls the operation of the train stop, the train stop in this case being arranged for electro-pneumatic control. Two independent circuits are provided for the red light, one over the back contact on the DR and one over a proving contact on the train stop which will only be broken when the train stop is "off"; it will be obvious therefore, that whilst the train stop is moving from the "on" to the "off" position both aspects of the signal will be illuminated. The feature serves the purpose of providing a warning to the driver in the event of a train stop remaining in the "on" position when the signal has been cleared, as under these conditions both aspects of the signals would be illuminated and the driver would stop his train. Arrangements are also included to prove that the train stop has returned to its normal "on" position after the passage of a train; this is done by including a train stop proving contact in the circuit to the local winding of the overlap track relay so that the track relay will not become re-energised and in consequence the signal will not clear again, until the train stop has returned to the "on" position. In addition, where controlled signals are concerned arrangements are usually provided to prevent the signal lever being replaced to its normal position until the train stop has functioned correctly.

Fig. 24 shows an alternative arrangement for train stop proving. In this case an all-electric train stop is concerned and because of the current value for operating the train stop motor, this cannot be controlled direct over the supply leads to the signal control relay. A contactor is therefore provided which, when energised, completes the circuit for the train stop motor from a local supply. It will be seen that with the arrangements shown, the signal control relay cannot be energised until the train stop has been lowered and has made a proving contact in its "off" position, this being included in the circuit to the local winding of the signal control relay, which would be of the two-element two-position type. Although not shown, similar arrangements would be provided to prove that the train stop had returned to its normal position with the passage of a train.

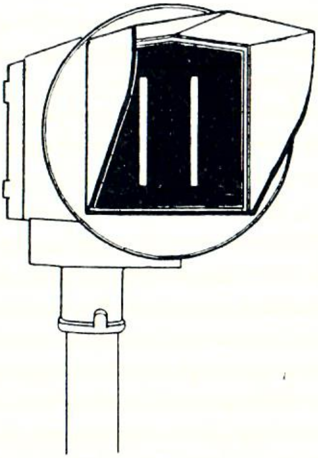
Route Indicators

A route indicator is a device for indicating in conjunction with a stop signal, the route to be travelled where two or more routes exist, thus eliminating the necessity for separate splitting signals.



TWO ASPECT COLOUR LIGHT SIGNAL WITH TRAIN STOP PROVING

FIG. 24



ILLUMINATED NUMBER OR FIGURE ROUTE INDICATOR

FIG. 25

Several types of route indicators are in general use, but they can be divided into two main categories viz:—

(i) those displaying an illuminated letter or figure to indicate the route set up, as is the case with indicators of the stencil type, the roller-blind type and multiple-lamp type. Fig. 25.

(ii) those of the position-light type, in which the route to be taken is indicated by the display of a row of lights set at an angle to the centre-line of the signal aspect. Fig. 26.

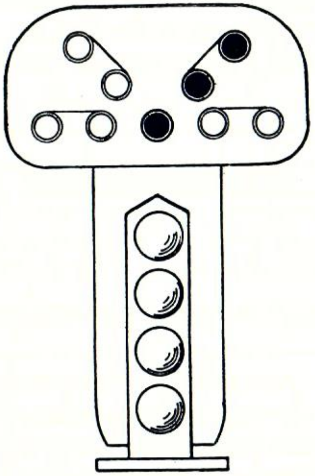
Where the position-light type of indicator is employed, the arrangements are usually such that the indicator is not illuminated for trains proceeding along the straight line. A clear signal without a route indication above it, therefore implies that the speed of the train need not be reduced; for this reason, the control circuits are so arranged that when a diverging route has been set up, the signal cannot be cleared until the route indicator has been illuminated. Similar proving arrangements are sometimes included with the other types of route indicators, but this feature is not considered quite so essential with these as the usual practice where they are used is to provide an indication for each route concerned.

Stencil type

Indicators of this type have no moving parts, a separate unit being provided for each route aspect to be displayed. Each unit comprises a box or compartment containing a lamp situated behind a glass screen and a stencil plate carrying the letter or figure which is to be indicated. The control arrangements are, therefore, extremely simple, the illumination of the appropriate lamp being all that is required.

Roller-blind type

Only one lamp compartment is provided with indicators of this type, the desired indication being obtained by moving a stencil to a position in front of the two lamps in this unit, as and when required. The various stencils are carried on a fabric screen which is operated, on the roller-blind principle, by means of an electric motor through suitable gearing. The lamps are not illuminated until one of the stencils is correctly positioned in



POSITION LIGHT JUNCTION INDICATOR.

FIG. 26.

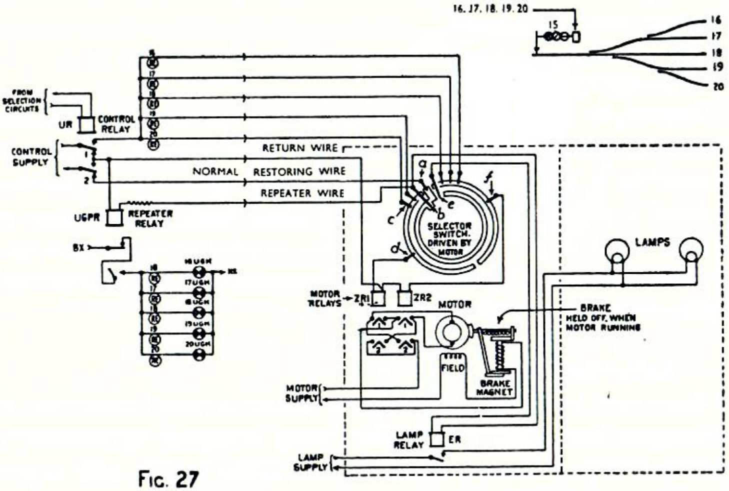


FIG. 27

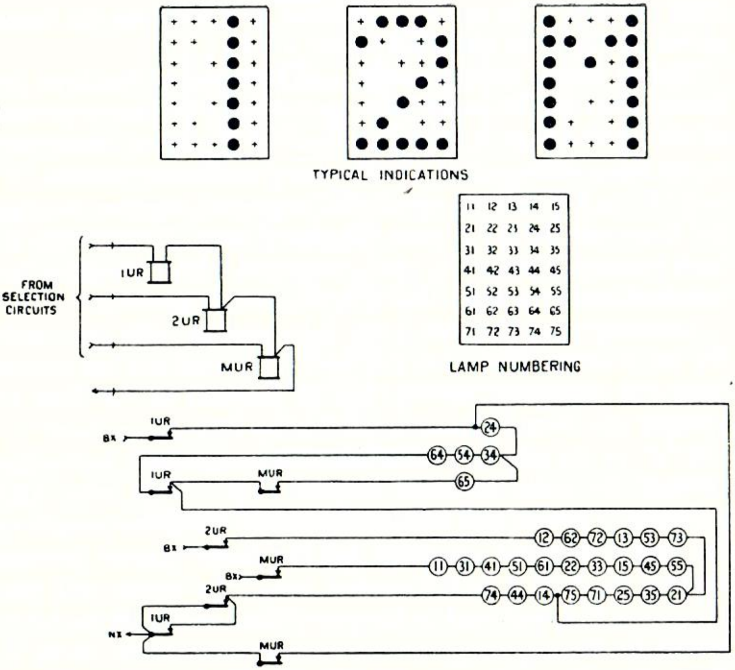
TYPICAL CIRCUIT ARRANGEMENTS
FOR
5 WAY ROUTE INDICATOR ROLLER-BLIND TYPE

front of them. The motor in addition to controlling the fabric screen also operates a selector switch.

Typical wiring arrangements for an indicator of this type are shown in fig. 27. When the indicator is normal an opaque portion of the fabric screen is located in front of the lamps, the actual lamps being extinguished. Under these conditions contacts *"a"* and *"b"* on the selector switch are connected together through the inner selector strip; when the control relay UR is making its back contacts a circuit is thus completed which energises the polarised repeating relay UGPR in the normal position.

Assuming now, that the route in connection with say, lever No. 20, is set up, then when this lever is reversed and the control relay UR energised, current will be supplied to the lines to energise the route indicator motor relay ZR1 as contacts *"c"* and *"d"* on the selector switch will be in contact with each other through the outer left-hand selector strip. With relay ZR1 energised, a circuit will be completed from the motor supply to the motor field and armature and the brake magnet winding through contacts 1 and 2 on this relay; the motor will thus commence to operate and in doing so will not only start the fabric screen in motion, but will also rotate the selector strips in an anti-clockwise direction. When the selector strips have moved to a position in which contacts *"c"* and *"d"* are no longer connected together, relay ZR1 will become de-energised and in consequence the motor will stop running and its brake will be applied. The fabric screen would by that time have moved to a position in which the required letter or figure stencil is located in front of the lamp. Furthermore, the selector strips will have reached the position in which selector contacts *"c"* and *"e"* are coupled together through the inner selector strip, so completing a circuit from the control supply to energise the lamp relay ER and the repeating relay UGPR, which is in series with it. Relay UGPR will, however, in this case be energised in the reverse position as the current will be flowing in the opposite direction. Relay ER when energised, will connect the lighting supply to the lamps and the stencil will thus be illuminated.

When the control relay UR is de-energised again, motor relay ZR2 will be energised as contacts *"a"* and *"f"* on the selector switch will be connected together through the outer right-hand selector strip. The motor will thus start operating

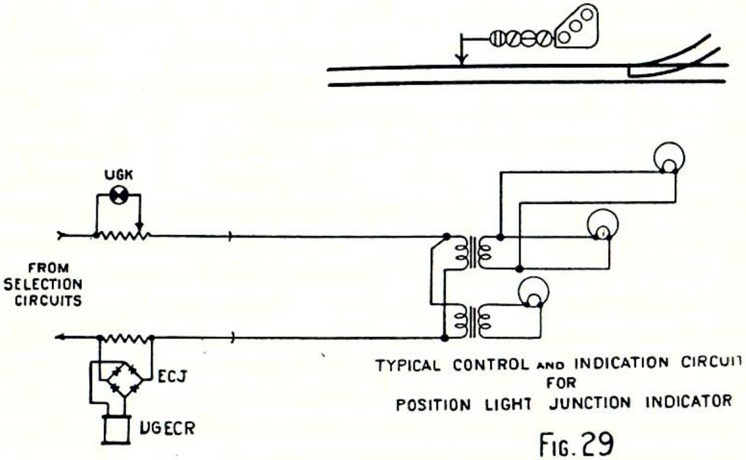

TYPICAL INDICATIONS

11	12	13	14	15
21	22	23	24	25
31	32	33	34	35
41	42	43	44	45
51	52	53	54	55
61	62	63	64	65
71	72	73	74	75

LAMP NUMBERING

TYPICAL CIRCUIT FOR 3-WAY MULTIPLE-LAMP TYPE ROUTE INDICATOR

FIG. 28.



TYPICAL CONTROL AND INDICATION CIRCUIT FOR POSITION LIGHT JUNCTION INDICATOR

FIG. 29

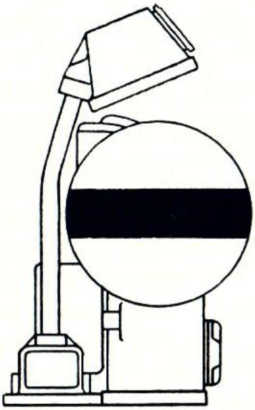
once more, but this time it will rotate in the opposite direction and the blind and the selector strips will be moved back to their normal position. When this point has been reached, the repeating relay UGPR will once again be energised to the normal position, thus proving the indicator to have reached the "on" position.

Multiple-lamp type

These indicators are sometimes known as the "Theatre" or "Music Hall" type. They are usually fitted with 35 or 49 lamps arranged symmetrically in horizontal and vertical rows behind a glass screen or cover glass. The indication is given by illuminating the approporiate lamps to form the required letter or figure. With some types, the lamps for each indication are wired in series, in which case, the failure of one lamp will extinguish the whole indication; with others, the lamps are wired in parallel and although the failure of one lamp will result in an incompleted indication being given, this in most cases will be readily distinguishable. In some indicators the lamps are controlled through relays, whilst in others pre-selector gear is used for this purpose, mainly where a large number of indications are concerned.

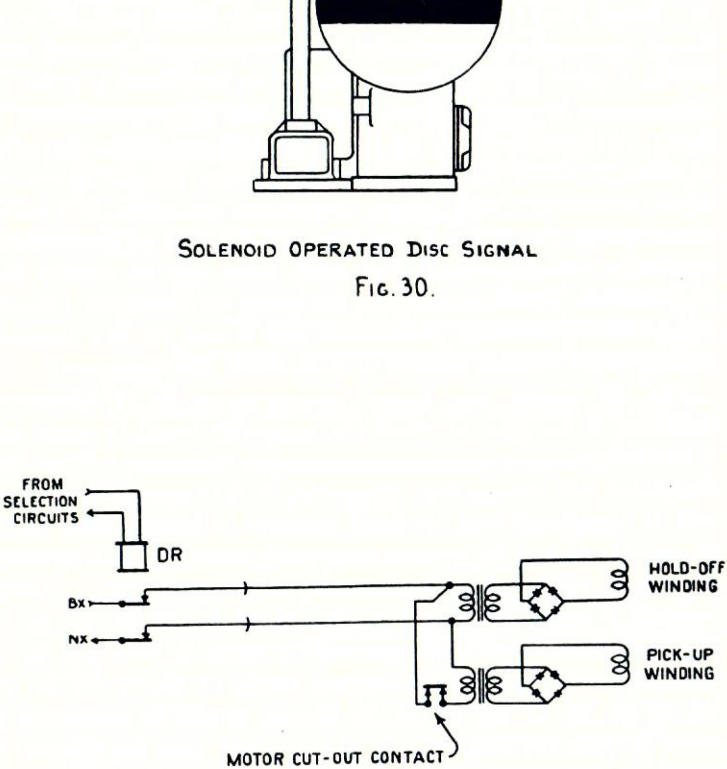
Fig. 28 shows the wiring arrangements for a three-way indicator of the type in which the lamps are wired in series and controlled through relays mounted in the indicator. From this diagram it will be seen that when relay 1UR is energised, a circuit will be completed over its front contacts to bring lamps 24,34, 54, 64, 14, 44 and 74 in series with each other. It will be found that these lamps when illuminated will form the fig. 1. With relay 2UR energised lamps, 12, 62, 72, 13, 53, 73, 21, 35, 25, 71 75, 14, 44 and 74 will be connected in series to form the fig. 2. Similarly with relay MUR energised lamps 11, 31, 41, 51, 61, 22, 33, 15, 45, 55, 21, 35, 25, 71, 75, 65 and 24 will be connected in series to form the letter M. It will be noted that the number of lamps in series at one time varies according to the aspect to be displayed; in order to maintain a standard voltage across each lamp the lighting arrangements are fed from a special transformer with varying secondary taps for each indication.

Indicating and lamp proving arrangements can be incorporated, although these have not been shown on the diagram. Any of the methods described in connection with multi-unit colour-light signals can be employed, but in some cases it is necessary



SOLENOID OPERATED DISC SIGNAL

FIG. 30.



TYPICAL CONTROL CIRCUIT
FOR
SOLENOID OPERATED SHUNT SIGNAL

FIG. 31

to provide some means for increasing the current in the lines to permit of this.

Position-light type

The application of this type of indicator was referred to in booklet no. 1. It will doubtless be remembered that the principal of the indicator consists of the display, above the main signal, of a row of three or five white lights on either side of the centre-line of the signal aspect as required, beginning at 45° from the vertical for the first diverging line, horizontal for the second and 45° beyond that for the third. Three diverging routes on either side of the main line can, therefore, be signalled.

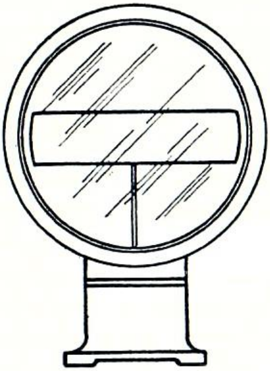
The wiring for a single-aspect junction indicator is shown in fig. 29. Where more than one aspect is required, the bottom light unit would be common to all indications two additional units being required for each aspect to be displayed. The indicating lamp and resistance is, therefore, located in series with the supply to the two uppermost lamps, the lamp proving rectifier, resistance and relay being inserted in the return wire. The latter equipment would be common to all aspects where more than one indication is concerned, but separate indicating lamps and resistances would be required for each aspect.

Attention has already been called to the importance of proving the indicator alight before a clear signal can be given, and the lamp proving relay is of course provided for this purpose.

Subsidiary Signals

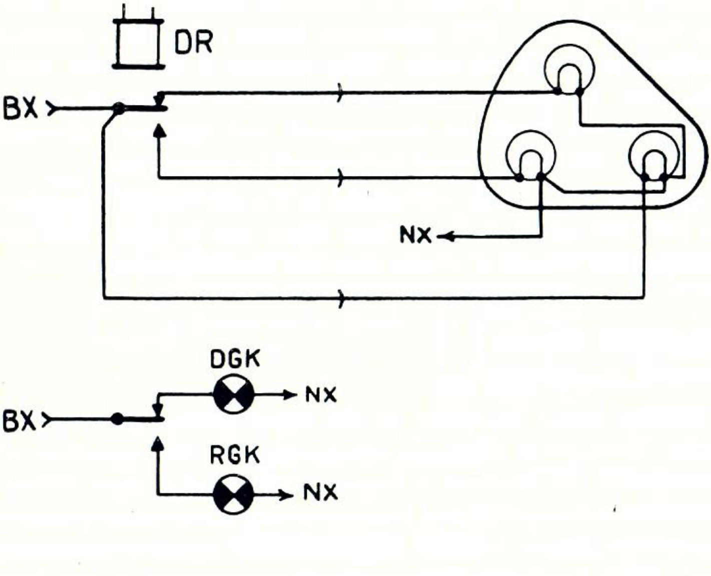
Disc Signals (Fig. 30)

Electric signal machines of the types previously described under "Semaphore Signals" can be used for the operation of disc signals. If, however, a simpler mechanism of more robust construction is required and power consumption is not of primary importance, then a solenoid operated shunt signal is sometimes used. With this type of signal, the disc is operated to the clear position by the energisation of the solenoid unit which forms part of it. The solenoid is provided with two windings, a "pick-up" winding and a "hold-off" winding, both of which are energised initially. A contact is, however, provided in the signal



ELECTRIC BANNER SIGNAL

Fig. 32



TYPICAL CONTROL AND INDICATION CIRCUITS
FOR
POSITION - LIGHT SHUNT SIGNAL

Fig. 33

which open-circuits the pick-up winding when the signal has cleared, thus minimising the current required for hold-off purposes as the hold-off winding is of higher resistance.

Where the same indication is required by night as by day, an external floodlighting unit is provided to illuminate the disc. In some cases, however, arrangements are made for the signal to be internally illuminated by means of a lamp located in the signal behind coloured roundels fixed in the disc; with such an arrangement a lamp proving relay is sometimes included too, for repeating purposes. Proving contacts to repeat the position of the disc are included with each type of signal so that an indication in this connection can be given in the signal box. Typical wiring arrngements are shown in fig. 31.

Where a compressed air supply is available, electro-pneumatic mechanisms can, of course, be employed too for the operation of disc signals. The apparatus used in this connection, however, operates on the same principle as that described under the heading of "Semaphore Signals" and should, therefore, require no further explanation.

Banner Signals (Fig. 32)

These signals, although occasionally employed as running signals or as subsidiary signals, are used principally for repeating main signals. They take the form of a coloured banner, set against a white background, which is operated to the clear position by the energisation of a magnet. They are designed for operation on d.c. but where an a.c. supply is available, this can be used by incorporating a rectifier with each signal. The magnet is provided with two windings, one of which is of high resistance for hold-off purposes, and the method of control is somewhat similar to that for a solenoid operated disc signal; a wiring diagram in this connection has not, therefore, been included.

Position-light Shunt Signals (Fig. 33)

With shunt signals of the position-light type, two light units in the horizontal position are illuminated to give a danger indication, and two in the upper quadrant position for a clear indication. Typical wiring arrangements in this connection are shown in fig. 33. It will be seen that the light unit which is common to both indications is permanently alight, the other light unit to make up the complete indication being selected over contacts on the control relay. This arrangement is the more common, although sometimes the light units for each indication are wired in series with the result that the failure of one will extinguish the other.

Where position light signals are concerned it is often only necessary to repeat the condition of the control relay, as shown in fig. 33, instead of proving the lamps alight.